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Systematic Review
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# Mandibular growth after paediatric mandibular reconstruction with the vascularized free fibula flap: a systematic review

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*W.-B. Zhang, T. Liang, X. Peng: Mandibular growth after paediatric mandibular reconstruction with the vascularized free fibula flap: a systematic review. Int. J. Oral Maxillofac. Surg. 2016; 45: 440–447.* 

*Abstract.* The reconstruction of mandibular defects with vascularized fibula flaps remains challenging in the paediatric population. The ability of the reconstructed mandible to grow remains controversial, and associated factors are unclear. A systematic search of the English-language and Chinese literature was conducted for the period January 1989 to April 2014 using selected key words associated with the topic. Individual patients aged <18 years who underwent mandibular reconstruction with the vascularized fibula flap and had known outcomes related to growth potential were included. Data on postoperative growth and associated factors, including condylar management, age at reconstruction, malignancy, and postoperative radiotherapy or chemotherapy, were reviewed systematically. In total, 51 patients reported in 15 articles were included. The proportion of patients with a preserved growth potential (58.8%) was higher than that of patients with no growth potential. Condylar preservation and reconstruction during the rapid growth period showed a trend towards an influence on the growth potential. Reconstruction after benign lesion resection seemed to facilitate postoperative growth, while postoperative radiotherapy inhibited growth. Reconstruction after benign lesion resection, reconstruction between 8 and 12 years of age, and condylar preservation facilitate postoperative mandibular growth, while postoperative radiotherapy inhibits the same.

Key words: paediatric; mandibular reconstruction; vascularized fibula flap; growth potential.

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The vascularized fibula flap was first introduced by Hidalgo in 1989, and since then it has become a popular graft for use in mandibular reconstruction.[1] Compared with non-vascularized flaps, vascularized flaps offer the advantages of a minimal infection risk, a low absorption rate, the possibility of simultaneous implant insertion, and the ability to reconstruct soft tissue defects.[1–5] Furthermore, vascularized fibula flaps can adapt to bone defects of various shapes and provide large vessel length and calibre for microvascular anastomosis and a double cortex layer for implant stability. Therefore, this flap is considered feasible for adult mandibular reconstruction.[1,4]

However, mandibular reconstruction in the paediatric population remains a challenge,[4–24] although it is gradually evolving with the development of appropriate anaesthesia techniques. Paediatric mandibular reconstruction with the vascularized fibula flap was first reported in 1993.[4] Although the above-mentioned advantages, along with the high survival rate and minimal donor site morbidity, have lent immense popularity to this flap,[4,5] the postoperative growth potential of the neomandible remains controversial.[12,14–18,22] This uncertainty stems from several factors. Because the condyle is considered to be the growth centre for the entire mandible, its involvement by the lesion and preservation during surgery may affect the outcomes to a large extent.[12,16,22] Patient age, which is related to the growth rate, is another potential contributing factor,[7] along with factors such as malignancy and postoperative radiotherapy and chemotherapy. Impaired growth after surgery may affect functional and cosmetic outcomes, possibly leading to malocclusion and facial asymmetry.[12,16] Such undesired outcomes, in turn, may affect nutrient ingestion, general health, and even the self-esteem of the child throughout life. However, there appears to be no systematic review on this topic available in the literature.

Therefore, this systematic review was conducted to evaluate the mandibular growth potential after reconstruction using the vascularized fibula flap in children. Details relevant to postoperative growth and associated influencing factors were collected, and the general outcomes and effects of those factors were assessed.

## Patients and methods

### Study identification

An initial online search of the PubMed, Ovid, and Embase databases for English-language articles and of the China National Knowledge Infrastructure (CNKI) and Chinese Scientific and Technological Journal (VIP) databases for Chinese publications was conducted for the period January 1989 to April 2014. A broad search strategy was implemented, utilizing the following key words: 'mandibular reconstruction', 'paediatric', 'mandibular defects in children', 'vascularized fibula flap', and 'free fibula flap'. Two reviewers screened the titles and abstracts of the articles retrieved. Full-text articles were obtained for relevant studies and studies where the title and abstract information was insufficient to allow a consensus. The reference lists were also screened, and relevant citations were included in the next round.

### Study selection

Two reviewers obtained and evaluated the full-text of articles retrieved during the first search round and from the reference list search. The following inclusion criteria were applied: individual age at reconstruction of <18 years, mandibulectomy and reconstruction with the vascularized fibula flap as the primary clinical procedure, and available follow-up data on the postoperative mandibular growth potential. The exclusion criteria were as follows: age >18 years, preoperative radiotherapy or chemotherapy, and no data on the growth ability of the grafted fibula segment. Articles in languages other than English and Chinese were also excluded.

During the retrieval procedure, the first reviewer reviewed the abstract and selected studies according to the inclusion and exclusion criteria. The second reviewer then reviewed and checked all the abstracts again and made his selection using the same criteria. The entire text of all selected studies was reviewed again by both reviewers in detail. Any differences were then discussed in consultation with a third party, until consensus was reached.

### Study design

Considering the dearth of studies on the selected topic, those included in this review were limited to retrospective studies and case reports. There was no restriction on the publication date or status.

### Outcome measures

Data on specific variables, including patient age, sex, pathological characteristics (benign or malignant), condylar management, postoperative radiotherapy or chemotherapy, follow-up period, and outcomes related to neomandibular growth or facial symmetry, were collected from each article. Cases reported from the same medical centre were contrasted to match and identify duplicate patient cases.[4,5,12,13] The outcomes reported in the most recent study were adopted for such cases.

### Data extraction and analysis

The first reviewer collected the data and imported it into an electronic database (Microsoft Excel). The second reviewer checked the extracted data for omissions or inaccuracies. The two reviewers discussed any differences and arrived at a consensus after consultation with a third party.

For the selected studies, preserved growth potential or postoperative growth potential was identified as an obvious actual subsequent growth after surgery. When a study included patients with both condylar resection and preservation, patients with preservation were classified into a 'condyle preserved' group, while those with resection were classified into a 'condyle resected' group.

A systematic review was conducted for patients with available postoperative growth potential data. The following factors were evaluated: age, condylar management (preserved or resected), pathological characteristics (benign or malignant), and postoperative radiotherapy or chemotherapy. According to the results of an anthropology study, children aged from 8 to 12 years show a high-level mandible growth rate, thus this period was termed the rapid growth stage.[25] Based on this theory, the patients were divided into three age groups: 0–8, 8–12, and 12–18 years. The research and review strategy adopted in this study is presented in Fig. 1.

## Results

In total, 548 articles (167 in English and 381 in Chinese) were reviewed. Among these, 15 articles reporting the cases of 51 patients met the study inclusion criteria and were retrieved. Details of these 51 patients are presented in Tables 1 and 2.

Among the 51 patients included, postoperative growth potential was reported for 30 (58.8%) (Table 2). The results of the systematic review showed that 81.5% of patients with a preserved condyle presented postoperative growth potential of the reconstructed fibula segment, while growth potential was shown by only 50.0% of the patients with a resected condyle (Table 3). Of the patients aged from 8 to 12 years, 83.3% presented preserved growth potential, while the growth potential was also preserved in 60% of the patients over 12 years of age. However, only 42.1% of the patients aged less than 8 years showed growth potential. These results show that patients over 8 years of age, particularly those aged 8–12 years, presented good growth potential of the grafted fibular segment, while those under 8 years of age showed impaired growth (Table 3).

Of the 51 patients included, 34 presented with benign lesions, most of which

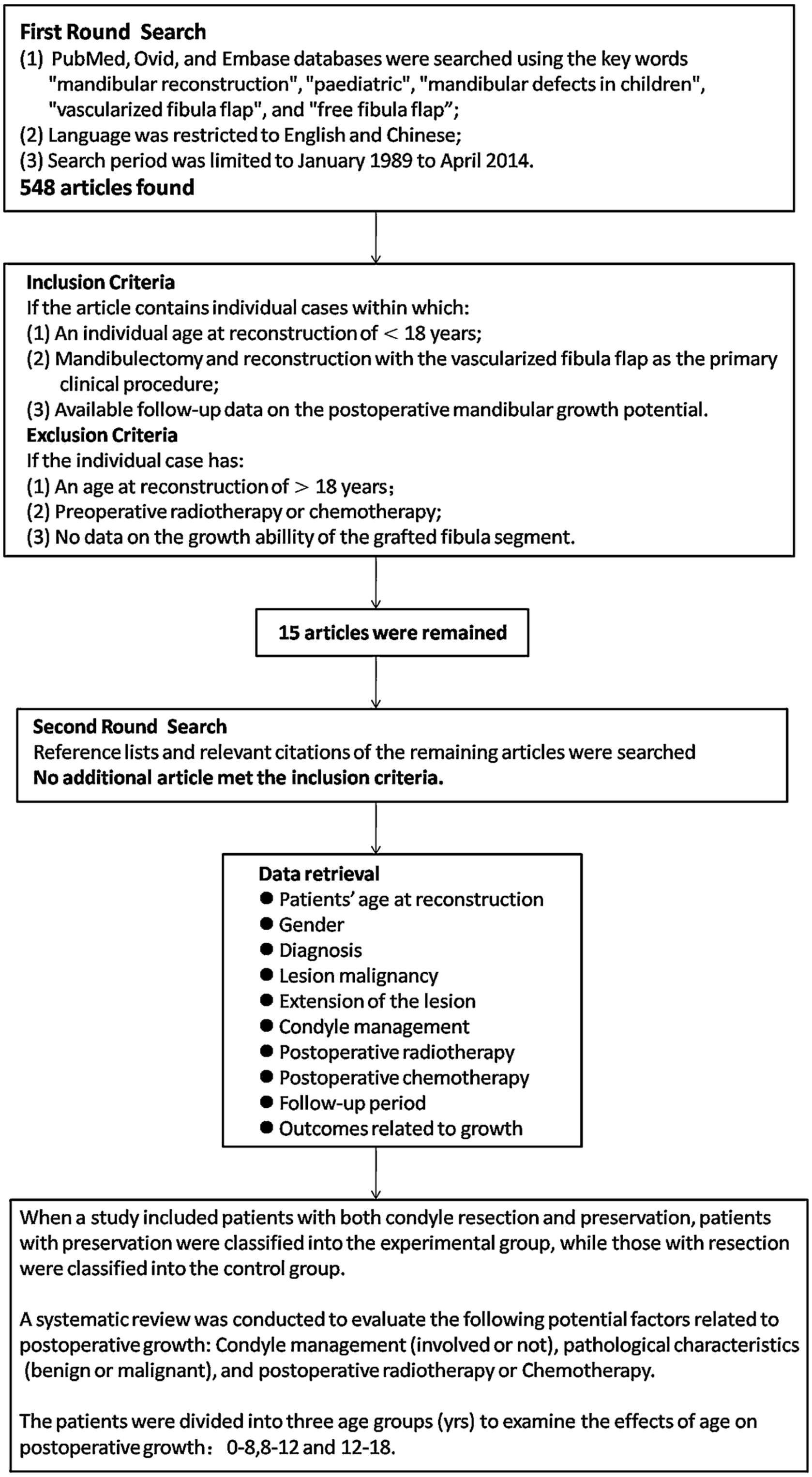


*Fig. 1.* Flowchart of the search strategy and data retrieval process used in this study.

were benign tumours such as ameloblastoma and ossifying fibroma. The other 17 patients presented with malignant lesions, most of which were sarcoma. Of the patients with benign lesions, 70.6% showed obvious growth after reconstruction, while only 35.3% of the patients with malignant lesions showed postoperative growth (Table 3).

Lastly, only one of the six patients (16.7%) who underwent postoperative radiotherapy showed growth potential, indicating that radiotherapy may inhibit the growth potential. On the other hand, the growth potential was preserved in 36.3% of patients who underwent chemotherapy after surgery, while 43.5% of patients who did not undergo postoperative chemotherapy also presented growth potential (Table 3).

## Discussion

Mandibular reconstruction with the vascularized fibula flap in paediatric patients was first reported by Posnick et al. in 1993.[4] Since then, several controversies have arisen, including the postoperative mandibular growth potential. However, not many studies on this subject have been reported in the last two decades. Moreover, there are no systematic reviews on this topic in the literature, thus researchers have to rely on data from individual case reports and retrospective studies. During the literature search for this review, it was found that some studies had reported a series of adult patients, with no description of individual paediatric patients. Even if the details were reported, the information was not adequate for inclusion in this review. Ultimately, only 15 articles were included in this systematic review. Although limited by the restricted availability of resources, the results of this review revealed that fibular segments grafted for the reconstruction of mandibular defects in paediatric patients can retain their ability to grow in certain cases.[22] However, the results are subjective and are affected by various factors, such as the limited sample size, evaluation methods, and follow-up periods.

For the studies selected, the growth potential of the reconstructed mandible was evaluated on the basis of the actual subsequent growth after surgery. Most studies evaluated outcomes through outline observation and radiological methods. Nevertheless, the indices used for evaluation differed. For outline measurements, the projective distance from the gonion to the midline in horizontal evaluation and from the tragion to the chin in sagittal evaluation are considered reliable.[22,25] However, the soft tissue condition, which can be related to skin paddle reconstruction, can affect bone tissue evaluation. Radiological methods can avoid this influence. Feasible solutions include measurement of the distance between the condylion and gonion, gonion and gnathion, and gnathion and condylion on a panoramic radiograph.[22] However, once these landmarks are reconstructed, the method becomes invalid and the condition becomes complicated. Digital

*Table 1*. Details of the 51 cases (15 articles) analysed in this study.

| First author | No. | Age, y | Sex | Diagnosis | Malignancy | Extension of the lesion | Condyle involved | Postop. XRT | Postop. Chemo | Follow-up | Outcome |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Posnick,[4] Iconomou,[5] Phillips[12] | 1 | 6 | F | Intraosseous arteriovenous malformation | Benign | Left parasymphysis to left ramus; 5 cm | No | No | No | 15 y | Growth |
| Posnick,[4] Iconomou,[5] Phillips[12] | 2 | 6 | M | Primitive neuroectodermal tumour | Malignant | Left parasymphysis to right angle; 10 cm | No | No | Yes | 14+ y | Growth arrested |
| Iconomou,[5] Phillips[12] | 3 | 7 | M | Recurrent aggressive fibromatosis | Benign | Right parasymphysis to right condyle;12 cm | Yes | No | No | 15 y | Growth arrested |
| Iconomou,[5] Phillips[12] | 4 | 17 | F | Ewing sarcoma | Malignant | Left parasymphysis to left subcondyle; 10 cm | No | NA | NA | 6+ y | Growth arrested |
| Iconomou,[5] Phillips[12] | 5 | 17 | F | Hemifacial microsomia and frontal dysplasia | Benign | Left angle to left condyle; 8 cm | Yes | No | No | 6+ y | Growth arrested |
| Iconomou,[5] Phillips[12] | 6 | 3 | M | Fibrous dysplasia/ossifying fibroma | Benign | Right parasymphysis to left angle; 9 cm | No | No | No | 6+ y | Growth arrested |
| Phillips,[12] Fenton[13] | 7 | 5 | M | Metastatic retinoblastoma | Malignant | Left body to right body | No | NA | Yes | 4 y | Growth arrested |
| Olvera-Caballero[9] | 8 | 10 | M | Giant dental cyst | Benign | Left condyle to midline | Yes | NA | NA | 1 y | Growth |
| Olvera-Caballero[9] | 9 | 10 | M | Osteoid osteoma | Benign | Chin to the right ascending ramus | No | NA | NA | 1 y | Growth |
| Olvera-Caballero[9] | 10 | 15 | F | Ameloblastoma | Benign | Chin to the right mandibular angle | No | NA | NA | 1 y | Growth |
| Olvera-Caballero[9] | 11 | 10 | M | Ossifying fibroma | Benign | Left mandible body to left condyle | Yes | NA | NA | 1 y | Growth |
| Olvera-Caballero[9] | 12 | 11 | M | Osteomyelitis | Benign | Right mandible body to right condyle | Yes | NA | NA | 1 y | Growth |
| Olvera-Caballero[9] | 13 | 9 | M | Loss of bone after wound infection | Benign | Right mandible body | No | NA | NA | 1 y | Growth |
| Genden[7] | 14 | 8 | M | Aggressive juvenile fibromatosis | Benign | Left ramus, body, and hemisymphyseal portion of mandible | No | No | No | 4 y 2 mo | Growth |
| Nahabedian[11] | 15 | 10 | M | Ameloblastoma of the right mandible | Benign | Right angle to the condylar neck | No | NA | NA | 18 mo | Growth |
| Warren[14] | 16 | 6 | M | Fibrous dysplasia | Benign | Right mandibular angle to left parasymphyseal area | No | NA | NA | 9–14 y | Growth |
| Bilkay[15] | 17 | 14 | M | Osteosarcoma | Malignant | Mandible body | No | NA | NA | 2 y | Growth |
| Crosby[16] | 18 | 12 | F | Rhabdomyosarcoma | Malignant | Left condyle, 10 cm | Yes | No | No | 10 y | Growth |
| Crosby[16] | 19 | 5 | M | Desmoid fibromatosis | Benign | Left neck to parasymphysis, 6 cm | No | No | Yes | 6 y 5 mo | Growth |
| Crosby[16] | 20 | 7 | M | Giant cell granuloma | Benign | Right angle to left mid-body, 10 cm | No | No | No | 4 y 9 mo | Growth |
| Crosby[16] | 21 | 5 | F | Ewing sarcoma | Malignant | Right mandible, 7 cm | Yes | No | No | 4 y 9 mo | Growth arrested |
| Crosby[16] | 22 | 14 | M | Desmoid fibromatosis | Benign | Parasymphysis to body, 10 cm | No | No | No | 2 y 8 mo | Growth arrested |
| Crosby[16] | 23 | 14 | M | Osteosarcoma | Malignant | Left mandible, 8 cm | Yes | Yes | Yes | 2 y 4 mo | Growth |
| Crosby[16] | 24 | 12 | F | Rhabdomyosarcoma | Malignant | Left mandible, 7 cm | Yes | No | No | 2 y | Growth arrested |
| Crosby[16] | 25 | 6 | M | Desmoid fibromatosis | Benign | Right parasymphysis to left angle, 9 cm | No | No | No | 1 y 7 mo | Growth |
| Crosby[16] | 26 | 13 | M | Ewing sarcoma | Malignant | Left mandible, 10 cm | Yes | No | No | 1 y 6 mo | Growth |

Table 1 (*Continued*)

| First author | No. | Age, y | Sex | Diagnosis | Malignancy | Extension of the lesion | Condyle involved | Postop. XRT | Postop. Chemo | Follow-up | Outcome |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Crosby[16] | 27 | 13 | F | Ameloblastoma | Benign | Parasymphysis to parasymphysis, 6 cm | No | No | No | 11 mo | Growth |
| Crosby[16] | 28 | 9 | F | Ameloblastoma | Benign | Right mandible, 16 cm | No | No | No | 9 mo | Growth |
| Guo[17] | 29 | 18 | NA | Hemifacial microsomia, type 3 | Benign | NA | NA | No | No | 2+ y | Growth arrested |
| Guo[17] | 30 | 16 | NA | Lymphoepithelioma | Benign | NA | NA | Yes | Yes | 2+ y | Growth arrested |
| Guo[17] | 31 | 15 | F | Hemifacial microsomia, type 3 | Benign | Left ramus and condyle | Yes | No | No | 2+ y | Growth arrested |
| Guo[17] | 32 | 8 | NA | Fibrosarcoma | Malignant | NA | NA | Yes | No | 2+ y | Growth arrested |
| Guo[17] | 33 | 4 | NA | Gunshot wound to neck, chin | Benign | NA | NA | No | No | 2+ y | Growth arrested |
| Guo[17] | 34 | 13 | NA | Ewing sarcoma | Malignant | NA | NA | No | No | 2+ y | Growth arrested |
| Guo[17] | 35 | 11 | F | Ewing sarcoma | Malignant | Whole mandible | Yes | No | Yes | 2+ y | Growth arrested |
| Guo[17] | 36 | 17 | NA | Rhabdomyosarcoma | Malignant | NA | NA | Yes | Yes | 2+ y | Growth arrested |
| Guo[17] | 37 | 8 | M | Rhabdomyoma | Benign | Hemimandible | Yes | No | No | 2+ y | Growth arrested |
| Guo[17] | 38 | 5 | NA | Neuroectodermal tumour | Benign | NA | NA | Yes | No | 2+ y | Growth arrested |
| Guo[17] | 39 | 3 | NA | Rhabdomyosarcoma | Malignant | NA | NA | Yes | Yes | 2+ y | Growth arrested |
| Guo[17] | 40 | 10 mo | NA | Germ cell tumour | Malignant | Right hemimandible | Yes | No | Yes | 2+ y | Growth arrested |
| Sinno[19] | 41 | 1.7 | M | Fibromatosis (desmoid tumour) | Benign | Left mandible, 37 cm × 23 cm × 23 cm | No | NA | NA | 6 y | Growth |
| Li[18] | 42 | 12 | F | Ameloblastoma | Benign | Right angle to left body, approximately 10 cm | No | NA | NA | 23 mo | Growth |
| Li[18] | 43 | 13 | F | Ossifying fibroma | Benign | Lateral segment without condyle | No | NA | NA | 18 mo | Growth |
| Li[18] | 44 | 14 | M | Ameloblastoma | Benign | Lateral segment without condyle | No | NA | NA | 16 mo | Growth |
| Li[18] | 45 | 14 | M | Ameloblastoma | Benign | Hemimandible segment with condyle | Yes | NA | NA | 24 mo | Growth |
| Li[18] | 46 | 15 | F | Fibrous dysplasia | Benign | Central segment | No | NA | NA | 28 mo | Growth |
| Li[18] | 47 | 12 | F | Ameloblastoma | Benign | Lateral segment without condyle | No | NA | NA | 36 mo | Growth |
| Bianchi[22] | 48 | 16 | M | Ewing sarcoma | Malignant | Right second premolar to right condyle | Yes | No | Yes | 6 y | Growth |
| Bianchi[22] | 49 | 14 | M | Chronic sclerosing osteomyelitis | Benign | Left canine to left condylar neck | No | No | No | 6 y | Growth |
| Bianchi[22] | 50 | 8 | M | Embryonal rhabdomyosarcoma | Malignant | Right second premolar to right condyle neck | No | No | Yes | 5 y | Growth |
| Pierse[23] | 51 | 15 | M | Ganglioneuroma | Benign | Right condylar neck to right first premolar | No | No | No | 1 y | Growth |

y, years; mo, months; F, female; M, male; Postop., postoperative; XRT, radiotherapy; Chemo, chemotherapy; NA, not available.

*Table 2*. Case distribution.

| Variables | Number | Percentage (%) |
|---|---|---|
| Postoperative growth | | |
| Growth | 30 | 58.8 |
| Growth arrested | 21 | 41.2 |
| Condyle management | | |
| Preserved | 27 | 52.9 |
| Resected | 16 | 31.4 |
| NA | 8 | 15.7 |
| Age group, years | | |
| 0–8 | 19 | 37.3 |
| 8–12 | 12 | 23.5 |
| 12–18 | 20 | 39.2 |
| Malignancy | | |
| Benign | 34 | 66.7 |
| Malignant | 17 | 33.3 |
| Postoperative radiotherapy | | |
| Yes | 6 | 11.8 |
| No | 27 | 52.9 |
| NA | 18 | 35.3 |
| Postoperative chemotherapy | | |
| Yes | 11 | 21.6 |
| No | 23 | 45.1 |
| NA | 17 | 33.3 |

NA, not available.

three-dimensional (3D) stereophotogrammetry can also be applied to the analysis of mandibular growth, although this method focuses primarily on the facial outline.[24]

Furthermore, the follow-up period may influence the outcomes. In patients with immature mandibles and grafted fibula segments, growth problems may manifest only after a period of some years, with no definite short-term outcomes. In a study by Olvera-Caballero, all seven patients, regardless of lesion extension, showed facial symmetry at the 1-year follow-up,[9] while in a series of cases reported from the Hospital for Sick Children in Toronto, some children with an initially normal appearance eventually required orthognathic surgery or new flaps to correct the configuration as they grew older.[4,5,12,13]

The growth potential of the reconstructed mandible may be driven from the residual mandible, the fibula flap, or both. Generally, the condyle is considered as the most important and reliable growth centre for the entire mandible.[7,25–28] Thus considerations of condylar management during mandibular surgery in patients with a maturing skeleton are of great significance. Whether reconstruction should be performed if the condyle is resected remains controversial. Because of the unsatisfactory outcomes and high complication rates, together with the belief in the possible growth potential of the contralateral intact condyle, Crosby et al.[16] recommended that the condyle should not be reconstructed. However, reconstruction remains a mainstream treatment option.

Options for condylar reconstruction include prosthetic materials and vascularized free flaps. Artificial prostheses, even titanium prostheses, are not suitable for growing children because of their fixed dimensions and the risk of plate fracture and wear of the head.[29] As one of the vascularized free flaps, costochondral grafts are biologically and anatomically similar to the condyle and can facilitate growth of the maturing skeleton.[11] However, unpredictable cartilage overgrowth, which can be sensitive to the amount of cartilage on the graft and hormonal changes, is a possible adverse sequela.[30] Nonetheless, if the amount of the cartilaginous end cap on the fibula graft is controlled, and if surgery is performed at a young age, the application of this flap can be an excellent choice.[28] The free fibula flap is another alternative. When the vascularized fibula flap is used for mandibular reconstruction, three condylar management strategies are used, of which one is used for condylar resection and two are used for condylar preservation.[30] The first is the fibula substitute condyle technique, whereby the distal end of the fibula flap is placed into the glenoid fossa to substitute for the condyle.[29,30] To alleviate the impact between the substitute condyle and glenoid fossa, soft tissue on the same vascularized flap is used to cover the fibula head.[30] This method is appropriate for patients with condylar involvement.[30] The second is the condyle graft technique, aimed at attaching the resected condyle as a non-vascularized transplant to the end of the fibula flap.[30] The third is a condylar preservation method whereby the condylar head is not resected and the reconstructive vascularized fibula flap is fixed to the *in situ* condylar head.[11] Because the majority of paediatric mandibular tumours are confined to the body and/or ramus, and because vascularity and supportive tissues are sufficient to maintain condylar viability and function, condylar preservation is a common practice.[11] As it does not disturb the original subtle structures of the temporomandibular joint, the third method is considered superior to the second one.[30] The maintenance of viability can conserve the growth potential of the native condyle, which is an advantage for paediatric mandible reconstruction.

This systematic review showed that the proportion of patients with postoperative mandibular growth potential was higher in the ‘condyle preserved’ group than in the ‘condyle resected’ group. Experimental condylectomy in animals showed that the mandible can maintain its growth potential and that the condyle can regenerate after surgery.[26] Rather than a growth centre, the condyle is more widely accepted as a growing site that can adjust to changes in other parts of the face.[26] Moreover, as discussed above, mandibular growth can be facilitated by other growth sites and surrounding tissues, such as the masticatory muscles.[25,27] Even if the condyle is preserved, the flap survives, and the bone unites at the junctions, growth is no longer consistent with that of the original mandible because of the interruption of integrity. Although the effects of condylar management on postoperative mandibular growth remain uncertain, condylar preservation is strongly recommended if possible.

Fibular growth is the other growth resource for a reconstructed mandible. It occurs in a classic endochondral pattern

*Table 3*. Review of factors related to the growth potential of the reconstructed mandible.

| Items | Outcomes | | Total | Proportion of growth |
|---|---|---|---|---|
| | Growth | Growth arrested | | |
| Condyle | | | | |
| Condyle preserved | 22 | 5 | 27 | 81.5% |
| Condyle resected | 8 | 8 | 16 | 50.0% |
| Age group, years | | | | |
| 0–8 | 8 | 11 | 19 | 42.1% |
| 8–12 | 10 | 2 | 12 | 83.3% |
| 12–18 | 12 | 8 | 20 | 60.0% |
| Malignancy | | | | |
| Benign | 24 | 10 | 34 | 70.6% |
| Malignant | 6 | 11 | 17 | 35.3% |
| Postoperative radiotherapy | | | | |
| Yes | 1 | 5 | 6 | 16.7% |
| No | 13 | 14 | 27 | 48.1% |
| Postoperative chemotherapy | | | | |
| Yes | 4 | 7 | 11 | 36.3% |
| No | 10 | 13 | 23 | 43.5% |

with three ossification centres: one in the shaft and one in each of the distal and proximal epiphyses.[7] To preserve the stability of the common peroneal nerve and the lateral malleolus, the epiphyseal plates are not grafted in mandibular reconstruction. However, if the native mandibular epiphyseal plates are uninterrupted, the grafted fibula flap will accommodate continued mandibular growth. Moreover, radiographic measurements suggest that growth is facilitated by both the residual mandible and grafted fibula bone.[16] Furthermore, removal of the fixture devices, such as the reconstruction plate, which may impede the growth of the reconstructed mandible, should also be considered.[16]

The mandibular and fibular growth rates are age-related. According to an anthropological study, the mandibular width and height show significant increases between 1 and 5 years of age, while mandibular depth shows a greater increase after 5 years. Typically, mandibular width increases rapidly before 4 years of age and between 8 and 12 years; height and depth show a similar pattern.[25] In this review, more than 50% of children aged below 8 years showed impaired growth after reconstruction, whereas most children aged 8–12 years, which is the rapid growth period, showed strong growth potential after reconstruction. With regard to the fibula, the growth plates fuse around 15 years of age in girls and 17 years in boys.[7]

With regard to the effect of pathological characteristics of the lesion on the postoperative growth potential, no specific related studies were found. However, according to the review of all the collected cases, the proportion of patients with continued postoperative mandibular growth was higher among those with benign lesions (70.6%) than among those with malignant lesions (35.3%).

To date, there is no related study with a focus on the effects of postoperative radiotherapy or chemotherapy on the growth potential of paediatric reconstructed mandibles. The effects of radiotherapy on craniofacial bone development are well recognized. Osteoblast and osteoclast development and proliferation can be disturbed, leading to impaired bone remodelling. The rays can also harm the vascular endothelial cells and affect the blood supply to the bone. Pathologically, radiotherapy can decrease cell numbers and cause tissue fibrosis and necrosis. These results indicate that the mandibular growth potential may be affected by postoperative radiotherapy. In this review, only 16.7% of patients who underwent postoperative radiotherapy maintained their growth potential. Compared with radiotherapy, chemotherapy seemed to be less harmful, although more than 50% of patients presented arrested growth.

Even though growth impairment is possible in children, methods for correcting undesirable facial asymmetry are available. Orthognathic surgery is considered when the skeleton reaches maturity, while new vascularized flap reconstruction using iliac or scapular flaps is considered at a younger age.[12,13] Nevertheless, factors associated with future growth, including age at reconstruction, condylar involvement, condylar preservation method, and duration of fixation, should be evaluated carefully before surgery to achieve the best functional and cosmetic outcomes.

Although considerable efforts were invested in collecting and summarizing the relevant literature, the available resources were sparse, and the results only show possible trends for general outcomes and factors affecting paediatric mandibular growth after reconstruction with the vascularized fibula flap. Further studies are required to clarify these findings.

In conclusion, in this systematic review, more than 50% of patients demonstrated mandibular growth after reconstruction. Condylar preservation appeared to have a positive impact on the postoperative growth potential. Reconstruction between 8 and 12 years of age also provided strong growth prospects. The growth potential of benign cases was higher than that of malignant cases. Postoperative radiotherapy was found to restrict the growth potential, while postoperative chemotherapy showed no effect. Therefore, the condyle should be considered a major resource for mandibular growth and should be managed prudently during surgery. Age at reconstruction and other factors should also be considered. Finally, further studies on paediatric mandibular growth after reconstruction with the vascularized fibula flap should be conducted.

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## Competing interests

None.

## Ethical approval

Not required.

## Patient consent

Not required.

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